

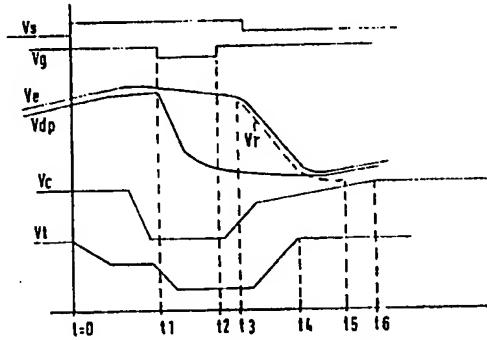
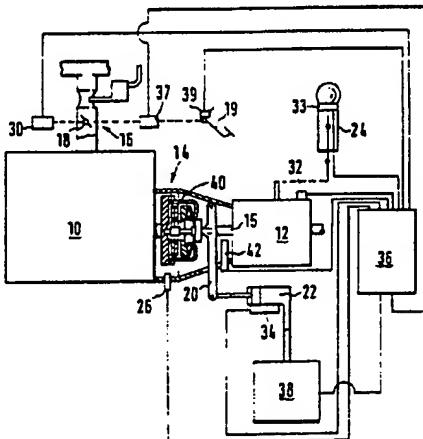


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## (54) Title: CLUTCH CONTROL SYSTEM



## (57) Abstract

A clutch control system comprises an engine speed sensor (26) for monitoring the speed of an engine (10), a clutch actuation sensor (34) for monitoring the operation of a clutch slave cylinder (22), a throttle position sensor (30) and a control unit (36) receives signals from the sensors (26, 34, 30) and determines when clutch control is required. When it is, the control unit switches to a reference mode in which, in a continuous closed loop operation, an engine speed signal  $V_e$  is compared to a reference speed signal  $V_r$  and the clutch is engaged or disengaged slightly to make the engine speed approach the reference speed.

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CLUTCH CONTROL SYSTEM

This invention is concerned with the control of the clutch in a vehicle which has a semi automatic or fully automatic transmission.

Patents GB 2 088 007, GB 2 079 888 and GB 2 074 884 describe means for controlling a vehicle clutch when taking up from rest which use the concept of a closed loop control whereby the engine speed is controlled so as to equal a pre-calculated reference speed by varying the degree of engagement of the clutch. By this means it is possible to ensure that the vehicle moves off smoothly from rest, either gently or vigorously according to the drivers wishes, whether the vehicle is on the flat or mounting a hill.

Patent application WO 89/10282 describes a control system which includes control of the clutch during a gear change, and patent application WO 89/03318 describes the control of the clutch during normal driving in a manner which eliminates driveline shock due to sudden changes of throttle. Both of these patent applications describe systems which calculate a degree of engagement of the clutch intended to give an optimum slip torque, but due to inherent variability in the performance of the friction material of the clutch facing the

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final effect may be slightly too harsh or too soft. It is the object of the present invention to extend the concept of the closed loop control of the first mentioned patents to the control of the clutch in general driving in non-takeup gears to improve the smoothness of the ride during gear changes, sudden throttle manipulations and other disturbances.

Other systems are known in which the engine speed is compared with the driven plate speed directly, and which then attempt to set this difference at a finite value such as 150 rpm. It is a further advantage of the system here described that by comparing engine speed with a correctly chosen reference the difference should be close to zero, which means that the scaling of the parameter representing the difference can be more advantageously chosen, enabling the control system to work with greater accuracy. If the system is implemented in a microprocessor the calculations within the speed loop need to be repeated at a greater frequency than other calculations. The design of the loop so that error is near zero without further calculations is of assistance in minimising the calculation that has to be done within the loop.

The present invention provides a clutch control system for a vehicle having a clutch actuation means, a transmission and an engine, the system comprising sensing means including an

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engine speed sensor for producing an engine speed signal variable with the speed of the engine and a clutch position sensor for producing a clutch position signal variable with the state of engagement of the clutch; reference signal generating means for generating a reference signal; and a control means operable in a first mode wherein the control means compares the reference signal with the engine speed signal and operates the clutch actuation means so that the engine speed signal tends to approach the reference signal, and a second mode wherein the clutch actuation means is not controlled by a reference signal, the control means being arranged to switch between the two modes in response to signals from the sensing means.

Preferred embodiments of the present invention will now be described by way of example only with reference to the accompanying drawings in which:-

Fig 1 is a diagrammatic representation of a clutch control system according to the invention;

Fig 2 is a graph showing variation in time of various parameters within the system of Fig 1 during a gear change;

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Fig 3 is a graph showing variation in time of various parameters within the system of Fig 1 following a sudden demand for torque by a driver;

Fig 4 is a graph showing variation in time of various parameters of the system of Fig 1 when the engine speed falls below a set value.

Referring to Fig 1 a vehicle clutch system comprises an engine 10 and a gearbox 12 coupled through a friction clutch 14, via a gearbox input shaft 15. Fuel is supplied to the engine by a throttle 16 which includes a throttle valve 18 operated by accelerator pedal 19. The clutch 14 is actuated by a release fork 20 which is operated by a slave cylinder 22. The gearbox is operated by a gear lever 24. A sensing means comprising an engine speed signal generator comprising an engine speed sensor 26 which includes a transducer and produces a signal  $V_e$  proportional to engine speed; a throttle valve position sensor 30 which produces a signal  $V_t$  proportional to the amount which the throttle is open; a pedal position sensor 39 or torque demand sensor for producing a signal variable with the position of the accelerator pedal 19 ie. the demand for torque from a driver; a gear position sensor 32 which produces a signal  $V_g$  corresponding to the gear which is engaged; a knobswitch 33

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on the gear lever 24 which detects forces applied to the gear lever 24 by the driver and produces a signal  $V_s$  indicating an intention to change gear; an actuation sensor 34 which produces a signal  $V_c$  varying with the position of the slave cylinder; and a driven plate speed sensor 42 which produces a signal  $V_{dp}$  proportional to the speed of the gearbox input shaft 15, which is equal to that of a driven plate 40 of the clutch 14. Since the speed of the vehicle depends on the driven plate speed and the gear engaged, the driven plate speed sensor 42 acts in effect as a vehicle speed sensor. Signals from the sensors are transmitted to a control unit 36 which controls the actuation of the clutch 14 via a hydraulic control 38. The control unit 36 includes a reference signal generator for generating a reference signal  $V_r$ . The throttle signal  $V_e$  whose idealised profile is shown in Figure 2 is typical for a driver operated throttle. This signal can be utilised if desired for the operation of an automatic throttle control 39 operated by the control unit 36. The throttle control 37 is operated by the control unit 36 so that it can open or close the throttle independently of the accelerator pedal 19.

Referring to Figure 2, while the vehicle is driving for example in second gear and accelerating, the control system is in a normal or drive mode in which no clutch movement is

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required. At time  $t = 0$  the driver moves the knobswitch 33 indicating that he intends to change to third gear. The control system then switches to an automatic mode. Control of the throttle is taken from the driver and the throttle is closed by the throttle control 37 in two stages. The clutch is disengaged by the hydraulic control 38 between the two stages of throttle closing. Also as the throttle is closed the engine speed levels off gradually. At time  $t_1$  second gear is disengaged. Thereafter the driven plate speed is decreased rapidly by synchromesh and the engine speed decreases gradually. At time  $t_2$  third gear is engaged and clutch engagement begins. The clutch is engaged at a set rate control it reaches the minimum engagement limit or kiss point at  $t_3$ . The control system then switches to a reference mode, with the reference signal  $V_r$  being set to an initial equal to the engine speed signal  $V_e$ . The reference signal  $V_r$  then follows a curve of a predetermined general shape, falling off during initial clutch engagement and then rising as clutch engagement is completed. The engine speed follows the reference speed as described below. The exact shape of the  $V_r$  curve is dependent on how depressed the accelerator pedal 19 is so that if the driver wishes to accelerate quickly, the clutch will engage quickly. After a delay from engagement of third gear, the throttle valve 18 is opened at a steady rate until at  $t_4$  its position corresponds to the position of the

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accelerator pedal 19. Then control of the throttle is returned to the driver. At time t5 when the engine speed and driven plate speed are equal the control loop is abandoned and the clutch is engaged at a fixed gradual rate to full engagement to t6. The control system then switches to the normal or drive mode, awaiting another signal indicating that clutch control is again required.

In the reference mode the clutch engagement is governed by the control unit 36 so as to keep engine speed signal  $V_e$  equal to the reference signal  $V_r$ . This is done by a closed loop operation in which the engine speed signal  $V_e$  is compared with the reference signal  $V_r$  and an error signal  $V_s$  is produced which can be either positive or negative. The clutch is then engaged or disengaged to make the error signal tend to zero. That operation is continuously repeated. In this case because the engine is driving the driven plate, if  $V_e$  is greater than  $V_r$ , ie  $V_s$  is negative, the clutch is engaged slightly to slow down the engine. If  $V_r$  is greater than  $V_e$ , the clutch is disengaged to allow the engine to speed up.

The above operation for an up-change in gear ratio can be used in principle for a down-change in gear ratio.

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Referring to Figure 3, when, at time  $t = 0$  the throttle signal  $V_t$  falls below a set value  $V_n$ , the clutch is partially disengaged, and  $V_c$  decreases so that its torque transmitting capacity is reduced. While the throttle signal remains low or increases gradually, no clutch slip occurs. However if, at  $t_1$ , the accelerator pedal is depressed suddenly, by more than a set amount increasing the throttle signal, the control system switches to reference mode and a reference signal  $V_r$  is set at an initial value which is greater than the driven plate signal  $V_{dp}$ . This will cause the clutch to disengage and  $V_c$  to decrease and allow clutch slip so that the engine can speed up towards the reference value. That slip prevents the sudden throttle opening from producing a torque surge in the drive line. The reference signal  $V_r$  is then set to follow a precalculated profile returning to the driven plate speed after a short period, typically 400 ms. This causes the clutch to return to near full engagement in that period. When the engine speed and driven plate speed are nearly equal at  $t_3$  the clutch is engaged at a steady rate until full engagement at  $t_4$ . The conditions under which the clutch is initially partially disengaged may include a requirement that a low gear, such as first or second gear is engaged.

In a further application of the invention as shown in Figure 4 the control system is used to prevent the engine from

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rotating above a maximum safe speed while retaining maximum possible engine braking. Between times  $t_0$  and  $t_1$ , the engine speed and driven plate speed are identical as the vehicle accelerates with the clutch fully engaged.  $V_e$  and  $V_{dp}$  are in fact equal although they are separated in Figure 4 for clarity. At time  $t_1$   $V_{dp}$  and  $V_e$  reach a set value  $V_{em}$  which corresponds to the maximum safe engine speed. This may have occurred, for example if the vehicle brakes have failed on a downhill gradient and a low gear has been engaged for braking. The control unit therefore switches to the reference mode with the reference signal set to equal to  $V_{em}$ . In this case, in the reference mode, because the driven plate is driving the engine, if  $V_e$  is greater than  $V_{em}$ , the clutch is disengaged slightly to allow the engine speed to decrease, and if  $V_e$  is less than  $V_{em}$  the clutch engages slightly to produce further braking. When at time  $t_2$ , the driven plate speed falls below  $V_{em}$  the clutch will be fully engaged and the control signal switches out of reference mode. During the time period when  $V_{dp}$  is greater than the reference  $V_{em}$ , a warning device can operate to alert the driver to the fact that the clutch should not engage the engine because the driven plate speed is greatly in excess of the engine speed. This could occur if the driver accidentally engages 1st gear at high road speeds.

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The control unit can also be used to reduce driveline vibration as shown in Fig 5. When the engine is running slowly, irregularities in the engine rotation speed, caused for example by the firing of the cylinders, become noticeable. To prevent the irregularities from being transmitted to the gearbox the engine speed signal  $V_e$  is monitored and when it falls below a set value at  $t_1$ , the control unit switches to reference mode, the reference signal being set to remain a predetermined amount above  $V_{dp}$ . This keeps the clutch in a continuous state of slight slip and the irregularities in engine speed are not transmitted, or are only partially transmitted, to the driven plate and gearbox.

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CLAIMS

1. A clutch control system for a vehicle having a clutch actuation means, a transmission and an engine, the system comprising sensing means including an engine speed sensor for producing an engine speed signal variable with the speed of the engine and a clutch position sensor for producing a clutch position signal variable with the state of engagement of the clutch; reference signal generating means for generating a reference signal; and a control means operable in a first mode wherein the control means compares the reference signal with the engine speed signal and operates the clutch actuation means so that the engine speed signal tends to approach the reference signal, and a second mode wherein the clutch actuation means is not controlled by a reference signal, the control means being arranged to switch between the two modes in response to signals from the sensing means.
2. A system according to Claim 1 wherein the control means is arranged to switch from the second mode to the first mode in response to signals from the sensing means.
3. A clutch control system according to Claim 2 wherein

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when the control means switches to the first mode the reference signal is set to an initial value dependent on the instantaneous value of a variable vehicle parameter.

4. A clutch control system according to Claim 3 wherein the initial value of the reference signal is dependent on the instantaneous value of a plurality of variable vehicle parameters.
5. A clutch control system according to any one of Claims 2 to 4 wherein the reference signal varies in time with the value of at least one variable vehicle parameter.
6. A clutch control system according to any one of claims 1 to 4 wherein the reference signal varies in time according to a predetermined pattern.
7. A clutch control system according to any foregoing Claims wherein the sensing means includes a gear position sensing means for producing a signal to indicate a change of gear ratio of the transmission, the control means being arranged to cause the clutch to disengage prior to a gear change and to switch to the first mode during re-engagement of the clutch.

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8. A clutch control system according to Claim 7 wherein the control means causes the clutch to disengage at a predetermined rate.
9. A clutch control system according to Claim 8 wherein the control means switches to the first mode when the clutch is re-engaged to its minimum engagement limit.
10. A clutch control system according to any one of Claims 1 to 6 further comprising a torque demand signal generator for producing a torque demand signal variable with a demand for torque, the control means being arranged to switch to the first mode when the torque demand signal increases suddenly.
11. A clutch control system according to Claim 10 wherein the initial value of the reference signal is a predetermined amount greater than the engine speed signal.
12. A clutch control system according to any one of Claims 1 to 6 wherein the control means switches to the first mode when the control means detects that the engine speed exceeds a set maximum value, the reference signal representing a maximum permissible engine speed.

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13. A clutch control system according to any one of Claims 1 to 6 wherein the control unit switches to the reference mode when the engine speed signal falls below a predetermined value.
14. A clutch control system substantially as hereinbefore described with reference to the accompanying drawings.

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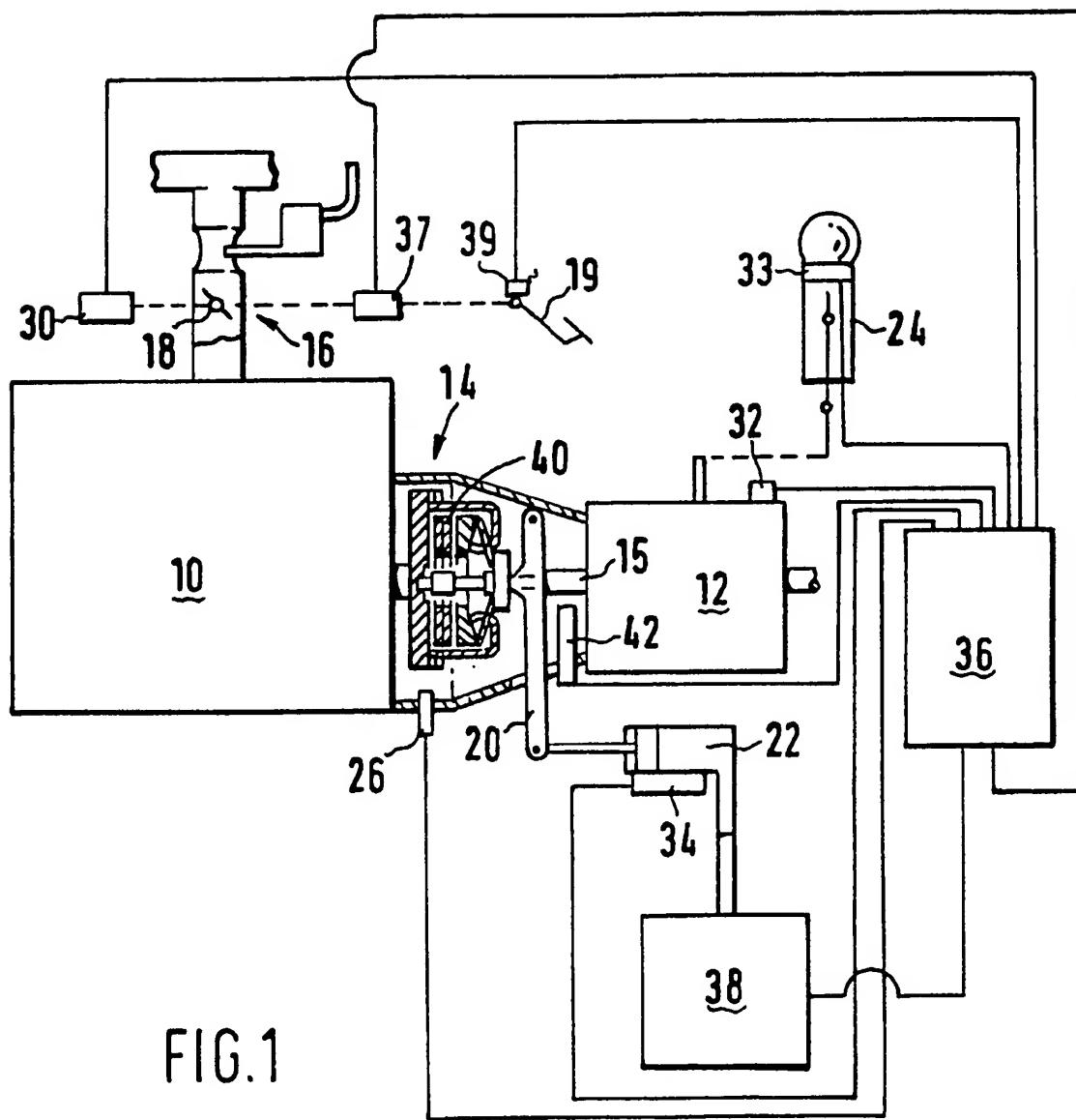
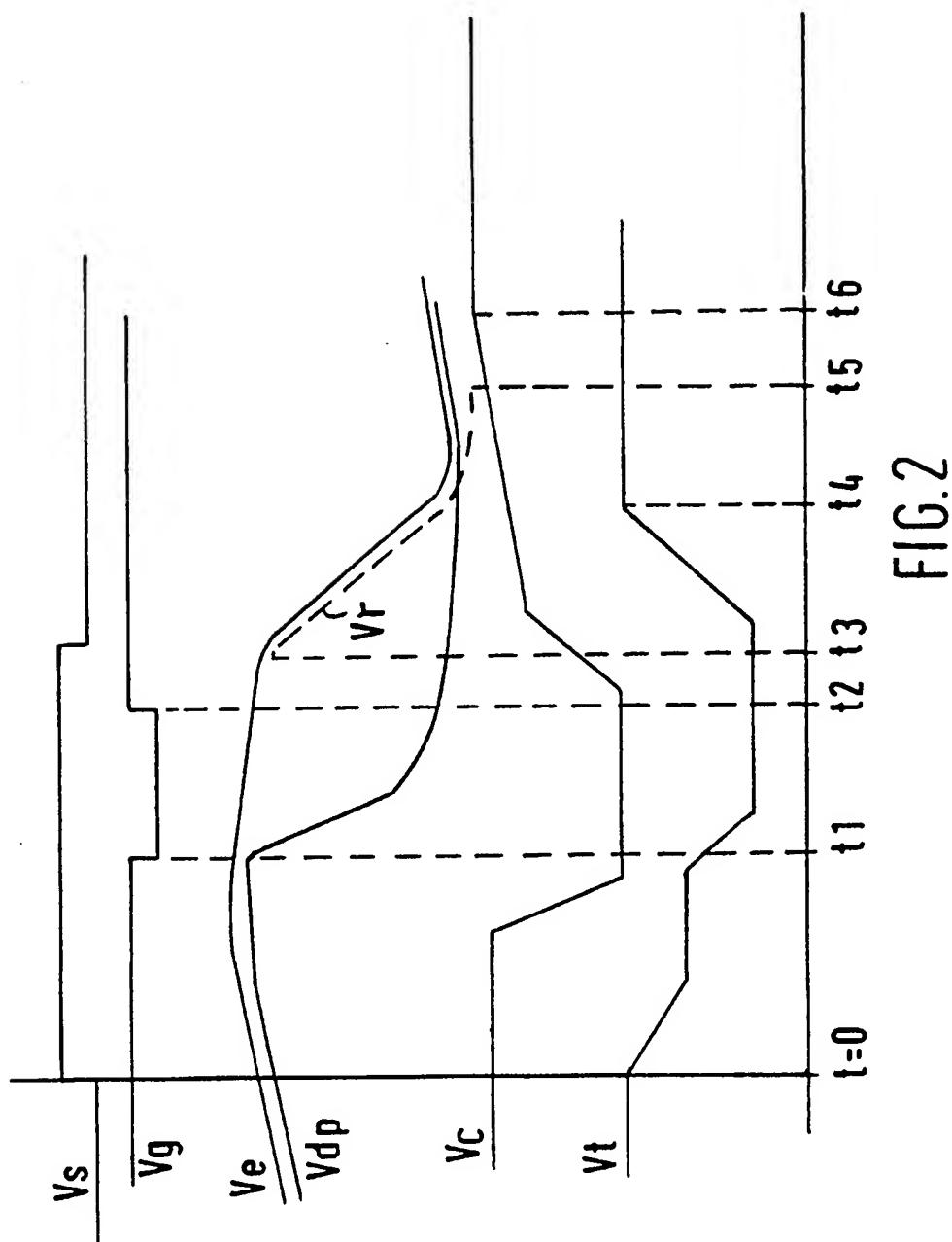
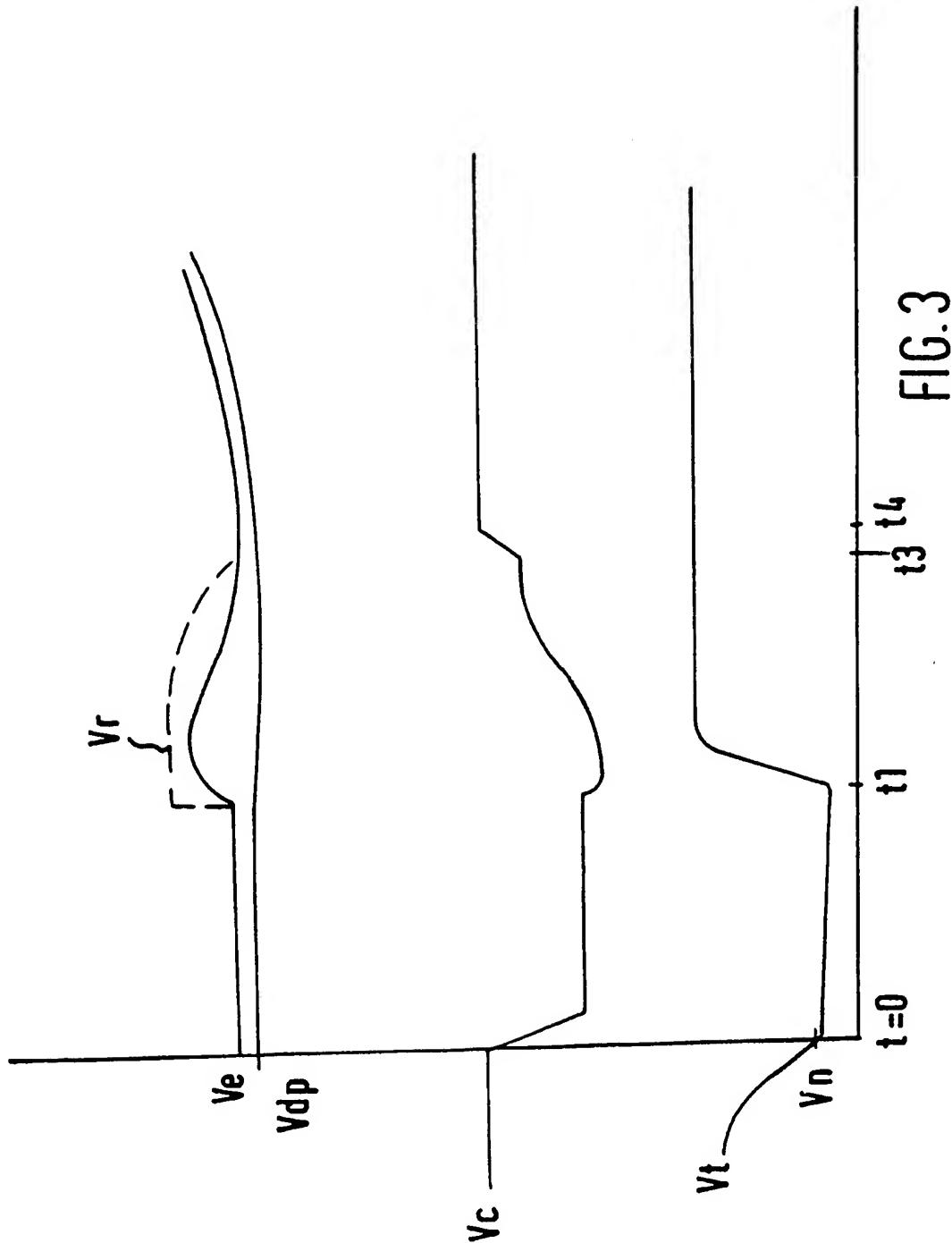


FIG.1

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3/4



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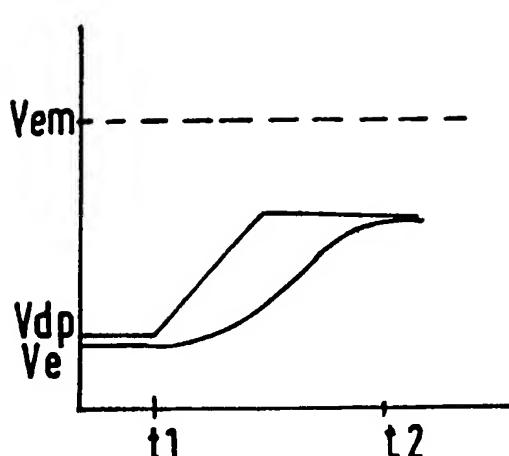


FIG.4a

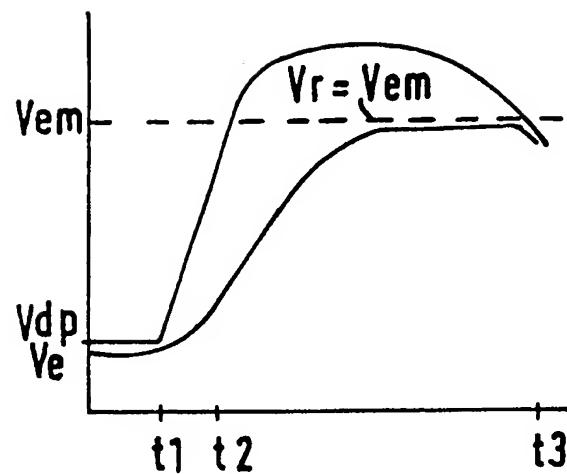


FIG.4b

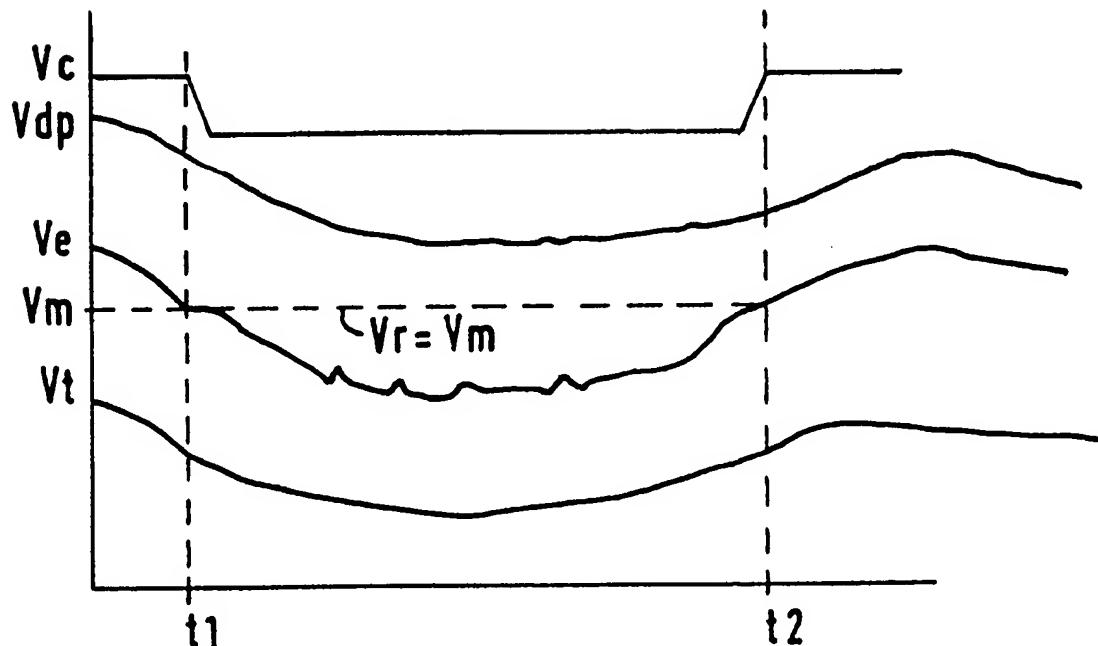


FIG.5

## INTERNATIONAL SEARCH REPORT

International Application No.

PCT/GB 91/02311

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)<sup>6</sup>

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 F16D25/14

## II. FIELDS SEARCHED

Minimum Documentation Searched<sup>7</sup>

Classification System	Classification Symbols
Int.Cl. 5	B60K ; F16D

Documentation Searched other than Minimum Documentation  
to the Extent that such Documents are Included in the Fields Searched<sup>8</sup>III. DOCUMENTS CONSIDERED TO BE RELEVANT<sup>9</sup>

Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
X	US,A,4 800 497 (KOORI YASUO ET AL.) 24 January 1989 see column 1, line 49 - column 2, line 48 see column 4, line 36 - column 7, line 42 see figures 3,4	1,2
A	---	11,12
A	US,A,4 558 772 (GRIMES, MICHAEL R ET AL.) 17 December 1985 see column 1, line 10 - column 2, line 6	1
A	---	1
	US,A,4 674 609 (STURGES, FRED D. ET AL.) 23 June 1987 see column 1, line 1 - column 2, line 11 see column 5, line 31 - line 45	1
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		-/-

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## IV. CERTIFICATION

Date of the Actual Completion of the International Search  12 FEBRUARY 1992	Date of Mailing of this International Search Report  20 FEB 1992
International Searching Authority  EUROPEAN PATENT OFFICE	Signature of Authorized Officer  VAN PROOIJEN T.

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International Application No.

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**III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)**

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	WO,A,8 910 282 (AUTOMOTIVE PRODUCTS PLC) 2 November 1989 cited in the application see the whole document ----	1,6,7,8
A	WO,A,8 903 318 (AUTOMOTIVE PRODUCTS PLC) 20 April 1989 cited in the application see the whole document ----	1,6,10

ANNEX TO THE INTERNATIONAL SEARCH REPORT  
ON INTERNATIONAL PATENT APPLICATION NO. GB 9102311  
SA 54820

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.  
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US-A-4558772	17-12-85	None		
US-A-4674609	23-06-87	None		
WO-A-8910282	02-11-89	EP-A- GB-A- GB-A- US-A-	0448551 2233053 2245036 5072815	02-10-91 02-01-91 18-12-91 17-12-91
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